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Mountain East-West and North-South Transportation Corridor - Air Quality Aspects

Report No. 46-20580

Mountain East-West and North-South Transportation Corridor - Air Quality Aspects

for

Regional Municipality of Hamilton-Wentworth
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Mountain East-West and North-South

Transportation Corridor - Air Quality Aspects

for

Regional Municipality of Hamilton-Wentworth

EXECUTIVE SUMMARY

A qualitative assessment of the potential impact on air quality of the proposed expansion of the roadway network within the Regional Municipality of Hamilton-Wentworth has been undertaken. A simple line source dispersion model was used to estimate short-term (1/2-hour) loadings attributable to both re-entrained dust and direct exhaust and tire wear emissions of total suspended particulate matter, as well as nitrogen oxides and carbon monoxide, in the vicinity of the proposed highway. These values then were compared to provincial standards and criteria. Factors which were taken into account in order to derive the appropriate emission rates included all available characteristics of the proposed highway and its traffic, and a very general definition of average meteorological conditions in Hamilton.

Predicted concentrations of these pollutants at a receptor 100 m from the middle of the highway were well within 1/2-hour point-of-impingement standard values in most cases. Under varying conditions, NO_x concentrations contributed between 15 and 35% of the 1/2-hour standard and CO varied from 6 to 72%, while TSP (direct) varied from 3 to 8% and TSP (re-entrained) varied from 60 to 132%. The re-entrained dust contributions which exceeded the standard occurred in the vicinity of the more heavily travelled sections of the proposed highway. However, when these half-hour calculations were normalized to derive a concentration representative of a 24-hour sampling time period, the resulting values all comply with the Ontario ambient air quality criterion, by a substantial margin. On the basis of these estimates, it is concluded that no adverse effect upon air quality is likely to occur as a result of the proposed highway.

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1. INTRODUCTION

An expansion of the roadway network within the Regional Municipality of Hamilton-Wentworth has been proposed. The findings and conclusions of a comprehensive investigation to identify the need, scope and timing for this expansion have been documented in the Environmental Assessment Submission entitled "Mountain East-West and North-South Transportation Corridor-Volume 1 and Volume 2", submitted by the Regional Municipality in December, 1982[1]. In the present situation, and as a result of future residential developments, there will be persons living near the proposed corridors. The Ontario Research Foundation have been retained by DelCan Limited on behalf of the Regional Municipality of Hamilton - Wentworth to undertake a qualitative assessment of the potential impact on air quality of the above-mentioned proposed expansion. Components of the assessment have included consideration of the results documented in the Environmental Assessment Submission, discussions with Mr. Dale Turvey of DelCan Limited, review of the ORF, et al Hamilton Road Dust study [2] in the context of the present study, and the use of a simple line source model to estimate loadings attributable to re-entrained dust and direct exhaust and tire wear emissions of total suspended particulate matter (TSP), nitrogen oxides (NO_x) and carbon monoxide (CO) in the general vicinity of the proposed highway. Information in the published literature pertaining to potential emissions from highway mobile sources, in conjunction with the general experience and knowledge of ORF staff in the areas of mobile emission sources, air quality and meteorology, also were used to complete the assessment.

2. PROVINCIAL STANDARDS

Air quality criteria and standards for most common air pollutants have been established in Ontario[3] using the best available information to

define a relationship between concentrations, exposure period and effects. Impact on human health, vegetation and materials are the most common effects considered in establishing these criteria. In Ontario, half-hour point-of-impingement standards are defined in Regulation 308 of the Environmental Protection Act. Schedule 1 covers 100 pollutants, but the major constituents attributable to mobile sources[4] which may be of some concern near roadways are listed below:

Contaminant	Half-Hour Point-of-Impingement Standard Concentration (ug/m^3)
Suspended Particulate (TSP)	100
Nitrogen Oxides (as NO_2)	500
Carbon Monoxide (CO)	6000
Hydrocarbons (HC)	no standard

3. PROPOSED EXPANSION OF ROADWAY NETWORK

The proposed roadway facility directly connects Highway 403 in Ancaster to the Queen Elizabeth Way in the eastern portion of the City of Hamilton. The roadway link is made up of two integrated facilities with a controlled access roadway North-South across the Escarpment, and a limited access arterial East-West across the Mountain area[1]. The rationale behind this proposed expansion, along with extensive maps illustrating the proposed route, are documented in detail elsewhere [1].

The roadway design chosen by the Study Team is described in great detail in the Environmental Assessment Submission (pg. 6-1). Highlights of relevance to this general assessment of air quality concerns include the fact that the East-West arterial is to consist of four lanes of limited access at intersections with the major North-South streets, with signal synchronization to ensure the steady progression of traffic at approximately 66 km/hr. In addition, the North-South segment

of the facility will be a basic six lane freeway facility narrowing to four lanes in the north section and accommodating traffic speeds of up to 100 km/hr.

Based on the facility characteristics, detailed calculations predicting CO levels in the vicinity of the proposed roadway were undertaken by the proponent[1] in conjunction with the Air Resources Branch of the Ministry of the Environment. Factors such as peak-hour volume, traffic speed, and the percent of truck traffic were used to derive the appropriate emissions factors. Results indicated that the maximum concentration which could be expected adjacent to the roadway did not exceed the CO criteria for a one-hour period, and it was concluded that the impact on air quality attributable to the proposed roadway was not significant. The specific objective of this study has been to extend these results to other pollutants through the use of simple modelling techniques.

4. EMISSION ESTIMATES

The potential emissions from vehicular traffic on the proposed facility have been derived on the basis of several recent US EPA emission factor studies [4,5], with the aid of approximate base quantities derived from the Submission[1], and information relevant to Canadian vehicles as opposed to U.S vehicles[6]. Emission factors were derived for the pollutants CO, NO_x, and TSP, with separate factors available for particle re-entrainment and particulate matter from both tire wear and direct exhaust. It is important to note that hydrocarbon emission factors are available from the literature, but the lack of a hydrocarbon standard to compare predicted levels against renders the calculation of hydrocarbon emissions of little practical interest.

The emission factors for CO and NO_x take into account seasonal

variations, travel speed, percent cold/hot starts, traffic density, traffic speed, fleet mix and the year for which the estimates apply[4]. Four scenarios were chosen for each of the two pollutants in an attempt to represent four different situations which may occur:

1. Winter, 90 km/hr travel speed, zero cold starts;
2. Summer, 90 km/hr travel speed, zero cold starts;
3. Winter, Stop and Go Traffic at approximately 20 km/hr, with approximately 25% cold starts; and
4. Summer, Stop and Go Traffic at approximately 20 km/hr, with approximately 25% cold starts.

All scenarios assumed a 1982 fleet mix. The 1982 vehicle fleet mix, derived by EPA[4], is as follows: light duty gasoline vehicles, 77%; light duty gasoline trucks, 13%; heavy duty gasoline vehicles, 4%; light duty diesel vehicles, 1%; heavy duty diesel vehicles, 3%; motorcycles, 1%.

The table below presents the emission factors corresponding to the above-mentioned conditions.

Emission Factors for NO_x, CO (g/Vehicle km travelled)

	Scenario			
Pollutant	1	2	3	4
NO_x	3.1	2.7	2.4	2.2
CO	13.6	11.1	78.0	51.7

The NO_x emissions factors do not vary considerably among the four scenarios, with the highest value occurring in cold air temperatures at high traffic speeds. There is, however, a large range of values representing the CO emission factors, with the highest emission factor for CO experienced at low travel speeds and cold air temperatures.

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Particle emission factors were derived for re-entrained dust, direct exhaust emissions and tire wear. Re-entrained road dust particles vary greatly in size; it is however only the finer particles which remain suspended in the atmosphere over long periods of time. The majority of particles greater than 15 um in diameter will be deposited relatively close to the source, the deposition profile varying as a function of atmospheric conditions and actual particle size. For the mean conditions assumed in this study (wind speed of 6 m/s), particles greater than 15 um have deposition velocities (v_t) ranging from approximately 6 to 100 cm/s[7]. Roughly half of the material greater than 15 um will be deposited within a distance of hu/v_t (h = height of release), or from 100 to 6 m[8]. Therefore, it was considered appropriate to derive an emission factor representing only the finer fraction of particles (less than or equal to 15 um).

The quantity of re-entrained dust less than or equal to 15 um generated by vehicular traffic on dry paved roads, per vehicle km travelled, has been estimated with the aid of an empirical equation[5] requiring input information on the following parameters (the value in brackets denotes the assumptions made for this study):

- o number of traffic lanes (4 for the East-West corridor and 6 for the North-South corridor)[1]
- o surface material silt content (10%)[9]
- o average vehicle weight (4 Mg)
- o surface dust loading (corresponds to % silt content and general maintenance of the road; 42 kg/km value reflects well maintained road)
- o particle size multiplier (.64; value indicates that majority of particles assumed to be less than 15 um in size).

Vehicle speed is not directly accounted for in this calculation. Accounting for all of the above-mentioned factors in the appropriate

manner results in an emission factor of 2.1 and 3.2 g/Vehicle km travelled for 6 and 4 lanes, respectively, for re-entrained dust. A current review of roadway emission factors[10] suggests that a value of 2.0 g/Vehicle km travelled is representative of the particle size fraction less than or equal to 15 um for major streets and highways, and it was this more general value which was used in the final analysis for both the 6 and 4 lane segments of the proposed roadway.

Total exhaust and tire wear dust emission rates are available for each general vehicle type[4]. To derive a single emission factor for these sources, each rate was weighted according to the 1982 fleet mix assumed for the CO and NO_x calculations. As well, the following general assumptions were made: that there are equal numbers of leaded and unleaded light duty gasoline users; that all heavy duty diesel-powered vehicles were predominantly 4-stroke, as were all motorcycles. The resulting particle emission factors are .11 g/Vehicle km travelled, for direct exhaust emissions and .12 g/Vehicle km travelled, for tire wear.

5. DISPERSION ESTIMATES

Dispersion calculations, using information approximated for the facility and the emission factors discussed previously, have been utilized to estimate the probable contribution of emissions from the proposed transportation corridor to local air pollution levels at nearby receptors. Although this is a widely accepted procedure, data derived must be considered as estimates in view of the many factors involved. These estimated contributions are then considered in the context of Ontario air quality standards (summarized in Section 2), in relation to existing levels of these pollutants attributable to the present road systems in Hamilton, and relative to levels reported for other cities.

The proposed transportation corridor, in simple terms, can be considered as two continuously emitting infinite line sources. Dispersion calculations, based on the Gaussian plume model with appropriate modifications to account for line sources[11], have been used to determine half-hourly point-of-impingement concentrations. Input data for the calculation of concentrations includes wind speed, appropriate emission rates (from Chapter 4), average traffic volumes for the roadway[1], the height of emission above the surface, and the plume spread for each atmospheric stability condition. Stability of the atmosphere describes the state of turbulence of the air, and is closely related to the vertical temperature structure. The Gaussian diffusion calculations can be expected to provide best estimates to within a factor of two, which is considered to be acceptable by regulatory agencies.

In favour of predicting higher (worst case) pollutant concentrations, the minimum angle of 45^{o} between source and receptor (model limitation) was chosen. This reflects impact on receptors adjacent to both the North-South and East-West facility under NE, SE, SW or NW winds. Somewhat lower concentrations (i.e., by approximately 30%) would be predicted by the model if a 90^{o} angle between source and receptor were used in the calculations (i.e., under N,E,S or W winds). An average wind speed of 6 m/s and a neutral stability class (class D) were assumed to prevail (class D was chosen as it is recorded most frequently in the major urban centres in Canada). Calculations were undertaken for a hypothetical receptor approximately 100 m from the center of the source, as the model does not allow closer resolution.

Traffic data obtained from the Submission (Figure 53)[1] have been used to define traffic flows for the roadways. An average flow of 3000 vehicles per hour in the East-West corridor and 6000 vehicles per hour in the North-South corridor has been assumed in this evaluation. Concentrations have been calculated for two traffic speeds, i.e. 20 km/hr and 90 km/hr. The summer and winter emission factor values for CO and

NO_x have been averaged to derive an annual figure. Predicted half-hour point-of-impingement concentrations for CO, NO_x and TSP are provided in Table 1, along with the appropriate standard for each pollutant.

Thus, it can be seen from Table 1 that the estimated levels of these airborne constituents attributable to the proposed transportation corridor are below the 1/2-hour air quality standard values, with the exception of the concentrations attributable to re-entrained dust adjacent to the North-South corridor (6000 veh/hr), which is estimated to result in 134 and 148% of the standard for 90 and 20 km/hr travel speeds, respectively. As well, the TSP levels attributable to the 3000 vehicles/hr (East-West corridor) approach the standard as a result of the contribution of the re-entrained dust factor, resulting in 67 and 74% of the standard for 90 and 20 km/hr travel speeds, respectively. Although the most commonly occurring stability and wind conditions were used, it should be noted that these half-hour calculations are based upon the assumption of relatively heavy traffic flows, and do not take into account periods of low traffic flows. As well, a receptor experiencing wind conditions directly perpendicular to the roadway could be expected to receive approximately 30% less TSP, (i.e., to result in 47 and 52% of the standard for 3000 vehicles/hr, and twice these values for the 6000 vehicles/hr case).

The CO levels predicted are generally consistent with the MOE results. That is, the results obtained here predict between 6 and 72% of the half-hour standard compared with the MOE results which predicted a maximum of 60% of the one-hour ambient air quality criteria. This confirms the basic validity of the simple modelling approaches being used in this study.

It should be noted that these qualitative calculations have not accounted for topographical effects which may influence the actual concentrations experienced at the receptors. To site one example, in the

TABLE 1

Predicted 1/2-Hour Concentrations (ug/m^3) 100 m from Roadway

	Travel Speed			
	90 (km/hr)		20 (km/hr)	
	3000 veh/hr	6000 veh/hr	3000 veh/hr	6000 veh/hr
NO_x Concentration	87	174	77	154
NO_x Standard	500	500	500	500
% of Standard	17%	35%	15%	31%
CO Concentration	372	744	2161	4322
CO Standard	6000	6000	6000	6000
% of Standard	6%	12%	36%	72%
TSP(re-entrained) Conc.	60	120	66	132
TSP Standard	100	100	100	100
% of Standard	60%	120	66%	132%
TSP (exhaust) Conc.	3	6	4	8
TSP Standard	100	100	100	100
% of Standard	3%	6%	4%	8%
TSP (tire wear)Conc.	4	8	4	8
TSP Standard	100	100	100	100
% of Standard	4%	8%	4%	8%
TSP (total) Conc.	67	134	74	148
TSP Standard	100	100	100	100
% of Standard	67%	134%	74%	148%

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situation of the proposed North-South Parkway near Pottruff Road and Queenston Road, the roadway is in a slight valley and the receptors are located on top of "bluffs" at both sides. Under stable (low wind speed) conditions, the emissions from the highway would be likely to impinge on the hillside, rather than at the top of the bluff, resulting in no significant concentrations at the receptor (night-time situation). With higher windspeeds, the plume is either channelled along the "valley", reducing the probability of plume impingement on the mountainside, or possibly could ride up the slope resulting in higher concentrations at receptors at the top of the bluff than could be expected in flat terrain. As well, wind cavities could be formed in the "valley" by the air flowing down over the terrain drop, which could possibly lead to higher concentrations on the opposite slope of the valley, but lower concentrations at the receptors above. Such effects cannot be assessed with the simple model used in this analyses. More detailed climatology of the area, complex diffusion calculations and detailed terrain information would be required.

Other studies have found that non-traditional particle emission sources (such as re-entrained dust, for example) are estimated to contribute up to about 40% of observed particle levels in urban areas [2]. An approximate mean value of 65 to 70 ug/m^3 of TSP (over a 24-hr averaging period) is felt to be representative of the levels currently existing in the Hamilton region. Table 2 summarizes the 24-hour suspended particulate data for the stations in Hamilton, during 1982 and 1983. Most of the stations are situated near the more industrialized sections of Hamilton. The Barton/Nash Road station, however, is situated quite close to the proposed North-South corridor. Forty percent of the mean range in Hamilton would indicate that approximately 26 to 28 ug/m^3 could be attributed to non-traditional sources. Half-hour point-of-impingement calculations such as used in this assessment can be normalized to longer sampling times, and a factor of .36 has been used to derive a concentration more representative of a 24-hour sample[8]. Application of this factor would result in estimated 24-hour values of 22 and 24 ug/m^3 for re-entrained dust for

TABLE 2

Summary of Hamilton 24-Hour Suspended Particulate Data for 1983 and 1982 (ug/m^3)

Station	1983 Arithmetic Mean	1983 Maximum	1982 Arithmetic Mean	1982 Maximum
Hughson/Hunter	72	188	80	250
City Hall	79	211	75	251
North Park	87	298	93	323
Kenilworth	62	229	72	200
Burlington/Leeds	106	254	114	370
Burlington/Wellington	78	195	82	201
Chatham/Frid	88	214	97	329
Barton/Wellington	85	282	95	395
450 Hughson St. N.	53	127	62	160
Upper Wellington/Inverness	60	183	68	205
405 Cumberland Ave.	67	191	71	211
Barton/Nash Road	63	149	70	185
Westdale Lib. King St. W/S. Oval	57	131	61	179
Range of all sites	53-106		61-114	

*24 hour standard is 120 ug/m^3

90 and 20 km/hr travel speeds for the East-West corridor, and 43 and 48 ug/m^3 for the North-South corridor, respectively. These compare quite well with the levels measured recently in Hamilton, as cited above[2]. The 24-hour standard for TSP is 120 ug/m^3 and thus, these adjusted 24-hour concentrations attributable to road dust do comply with this standard by a substantial margin.

Several other studies have been undertaken with the aim of characterizing urban suspended particulate matter, ranging in detail from experimental studies actually measuring particle resuspension with the aid of tracer particles[12] to larger scale urban aerosol characterization studies. In particular, a Philadelphia study[13] attempted to use semi-quantitative source apportionment to define re-entrained road dust contributions, and found this source to contribute from 12 to 50 ug/m^3 to the total TSP loading at individual sites located 15 to 60 m from a highway. Other studies, aimed at apportioning urban sources in general, estimated that road dust in Portland[14] (as part of a general category labelled "crustal" component) may contribute up to 39% of TSP levels, while auto emissions were 9%. In Boston [15], road dust was found to contribute approximately 8 ug/m^3 and vehicle emissions 4 ug/m^3 to total TSP loadings of approximately 50 ug/m^3, as measured at various sampling locations throughout the city, not specific to roads.

6. CONCLUSIONS AND RECOMMENDATIONS

It is concluded that the proposed transportation facility, namely the Mountain East-West and North-South Transportation Corridor in Hamilton, will comply with half-hour point-of-impingement air quality standards set by the Province of Ontario for the pollutants CO, NO_x and TSP with the exception of the re-entrained dust contribution in the more heavily travelled North-South corridor. However, calculations were based on the assumption of full capacity traffic volumes and did not account

for periods of low traffic flows. As well, the specific wind directions assumed (NE, SE, NW, SW) result in the highest predicted concentrations. Other directions could be as much as 30% lower. Overall, lower levels can be expected on a longer term basis, and a normalization of the 1/2-hour estimates to 24-hour values confirms this, with the resulting concentration estimate complying with ambient air quality criterion for all pollutants by a substantial margin. On the basis of these estimates, it is concluded that no adverse effect upon air quality is likely to occur as a result of the proposed facility.

Relative to existing standards, re-entrained dust represented the largest contribution of all the pollutants considered, and it is recommended that appropriate attention be given to the highway as a source of particulate matter, possibly through more complex modelling efforts (such as the MOE model and complex terrain models), and in future and present monitoring programmes in the vicinity of the propopsed roadway. However, it must be emphasized that re-entrained dust is unlikely to impact significantly on existing air quality in the area.

7. REFERENCES

(1) The Regional Municipality of Hamilton - Wentworth, "Mountain East-West and North-South Transportation. Corridor - Volume 1 - Environmental Assessment Submission", December, 1982.

(2) Ontario Research Foundation, et al. "An Assessment of Street Dust and Other Sources of Airborne Particulate Matter in Hamilton, Ontario", prepared for Environment Canada, Ontario Ministry of the Environment, Dofasco Inc., Stelco Inc., City of Hamilton, March, 1982.

(3) Government of Ontario, "Environmental Protection Act - Air Pollution Control (General) Regulations, R.R.O. 1980, Regulation 308.

(4) U.S. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors - Highway Mobile Sources", PB82-238305, March, 1981.

(5) U.S. Environmental Protection Agency, "Compilation of Air Pollutant Emission Factors - Third Edition, Supplement No. 14 (Including Supplements 1-7), PB83-250720, May 1983.

(6) Ontario Research Foundation and the MEP Company, "Area Source Emission Inventory of Nitrogen Oxides in Ontario" prepared for the Ministry of the Environment, Province of Ontario, September, 1983.

(7) Denison, P.J, et al, "Literature Review on Pollution Deposition Processes", prepared for the Alberta Oil Sands Environmental Research Program and Syncrude Canada Limited. AOSERP Report 50, 1979.

(8) Hanna, S.R. et al, "Handbook on Atmospheric Diffusion" prepared for the office of Health ,and Environmental Research, Office of Energy Research, U.S. Dept. of Energy, DOE/TIC-11223(DE82002045), 1982.

(9) Cowherd, C., Mann C.O. "Quantification of Dust Entrainment from Paved Roads", for presentation at the 69th Annual Meeting of the Air Pollution Control Association, Portland Oregon, June 27-July 1, 1976.

(10) Cowherd. C., Englehart, P.J., "Paved Road Particulate Emissions, Source Category Report, EPA-600/7-84-077, July 1984.

(11) Turner, D.B., "Workbook of Atmospheric Dispersion Estimates", U.S. Department of Health, Education and Welfare,. Publication No. 999-AP-26, 1969.

(12) Sehmel, G.A., "Particle Resuspension From an Asphalt Road Caused by Car and Truck Traffic", Atmospheric Environment, 7, pp. 291-309, 1973.

(13) Record, F.A., Bradway, F.M., "Philadelphia Particulate Study"; U.S. EPA Report No. EPA-903-1978-003, 1978.

(14) Cooper, J.A., Watson, J.G., "Portland Aerosol Characterization Study", Final Report to the Oregon State Department of Environmental Quality, 1979.

(15) Alport, D.J. Hope, P.K., "A Quantitative Determination of Sources on the Boston Urban Aerosol", Atmospheric Environment, 14, PP 1137, 1980.

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